# Investigating Potential Sources of Modulation Enhancement in Noise through Physiologically Recorded and Model Neural Responses


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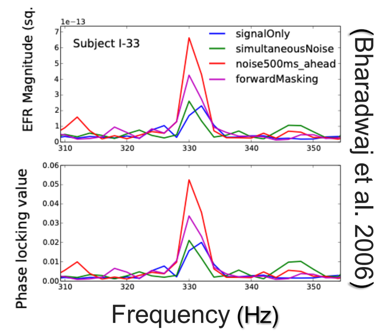
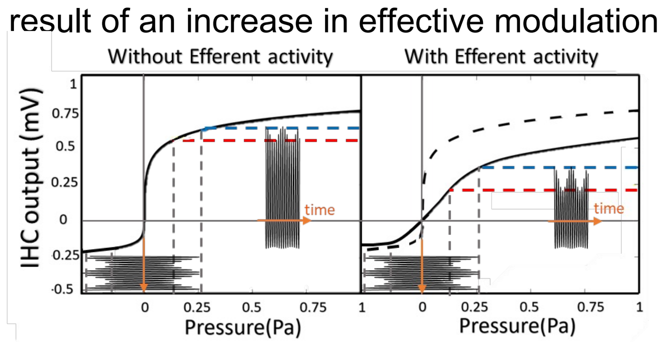
## Introduction

Hearing in noise is a challenge for everyone but even more challenging for people with hearing loss. Recent studies indicate that while listening to a signal, exposure to mild noise (20+ dB SNR) can lead to increased envelope-following responses (EFRs) and improved perception (Bharadwaj et al 2006, Billings et al 2020).

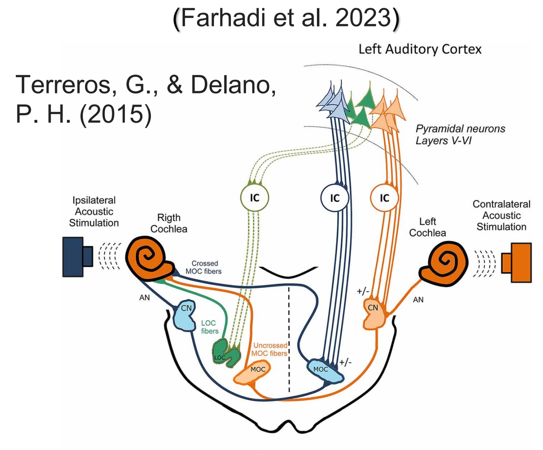



**The potential Role of Medial Olivocochlear (MOC) Efferent System:** The unmasking effect (neural coding enhancements) has been hypothesized to be related to the MOC efferent system, since middle-ear muscle effects were ruled out. This enhancement could be a result of an increase in effective modulation depth following the efferent activity. (See figure 2- right)




(Farhadi et al. 2023)

**Testing the Influence of Anesthesia and Carboplatin Exposure:** Anesthesia has been shown to suppress efferent activity (Boyev et al 2002), while carboplatin-induced selective inner hair cell (IHC) loss can impact the efferent system by altering the input to MOC via the brainstem.

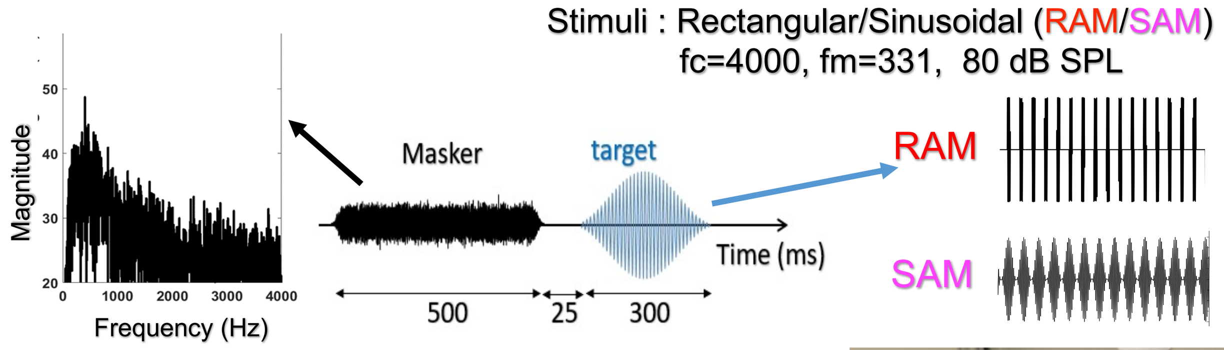



**Exploring Neural Mechanisms with Computational Modeling and Physiology:**
Utilizing computational auditory modeling and animal physiological experiments, this research aims to uncover the origins of brainstem modulation enhancement and gain a better understanding of the neural mechanisms involved in hearing in noisy environments.

## Methods

Stimuli : Rectangular/Sinusoidal (RAM/SAM)
fc=4000, fm=331, 80 dB SPL

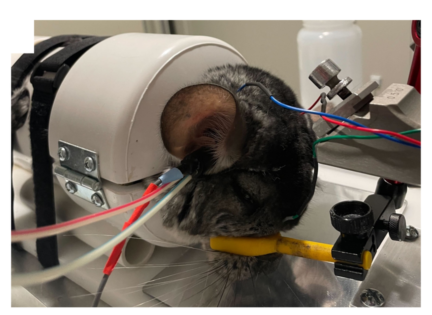
Forward Masking Ipsilateral Speech shaped noise with SNR 20,40 dB




**Physiological methods:**

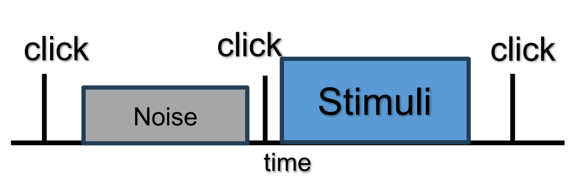
Normal hearing (NH) (n=3,2F), Carboplatin-exposed (CA) (n=3, 2F)

Data were collected in 3 anesthetic conditions:
1-Awake 2-Light sedation 3-Deep sedation



In the awake condition the animals were restrained in an animal holder (see Fig above)

- Sedation procedure: 4mg/kg xylazine SQ followed by either 40 (deep sedation) or 20 (light sedation) mg/kg ketamine SQ.
- Carboplatin exposure: chinchillas were given 38 mg/kg carboplatin IP about 2 years ago. this dosage tends to create 10-15% IHC loss uniformly across the cochlea (Axe, 2017)
- EFR response using subdermal electrodes, phase locking value (PLV) used for the analysis.
- Transitory evoked otoacoustic emissions (TEOAEs) were collected (Interleaved with the masker and signal for each EFR) to examine the effect of the masker and signal on the efferent system. Goodman et al 2021 methods were used for analysis of this data.

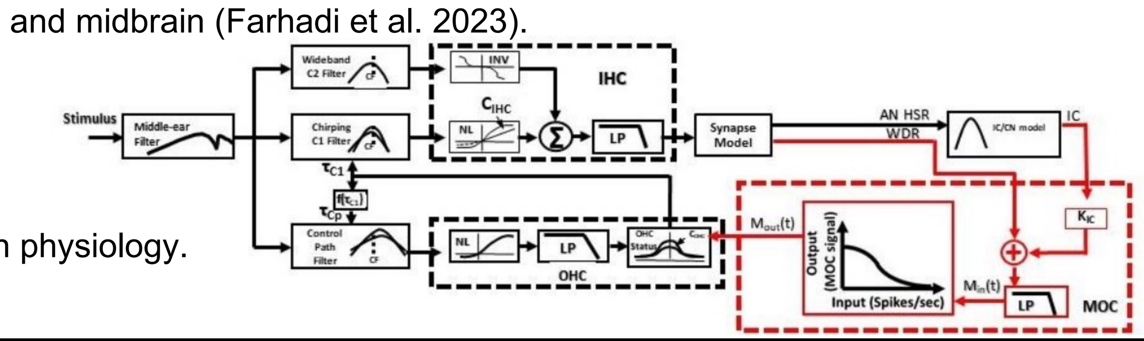



**Modeling Methods**

Subcortical auditory model was used with inclusion of MOC efferent dynamic gain control system with Inputs from auditory brainstem and midbrain (Farhadi et al. 2023).

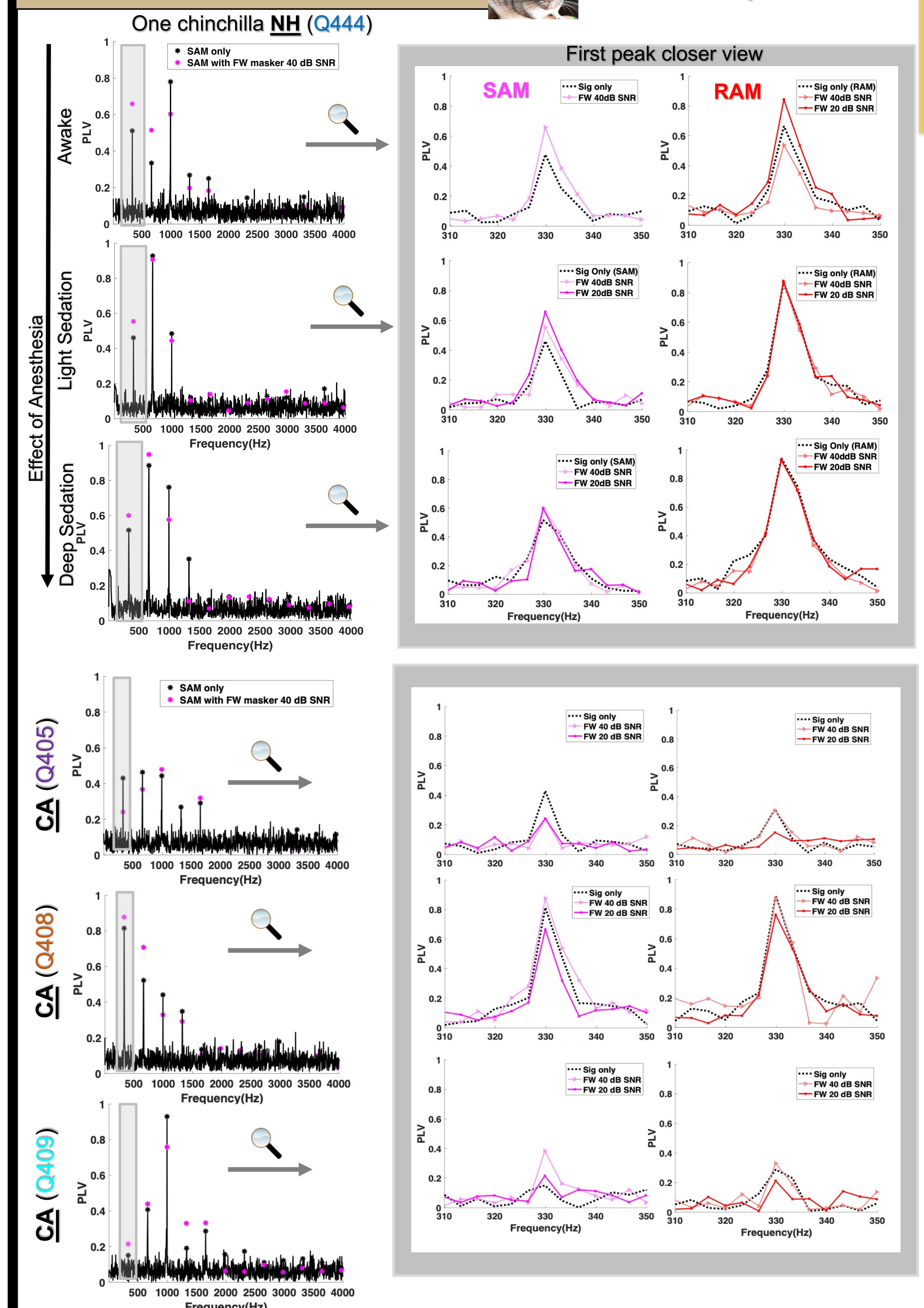
- Auditory nerve (AN),
- Inferior colliculus (IC),
- and EFR response

were simulated to compare with physiology.




## Physiology Results

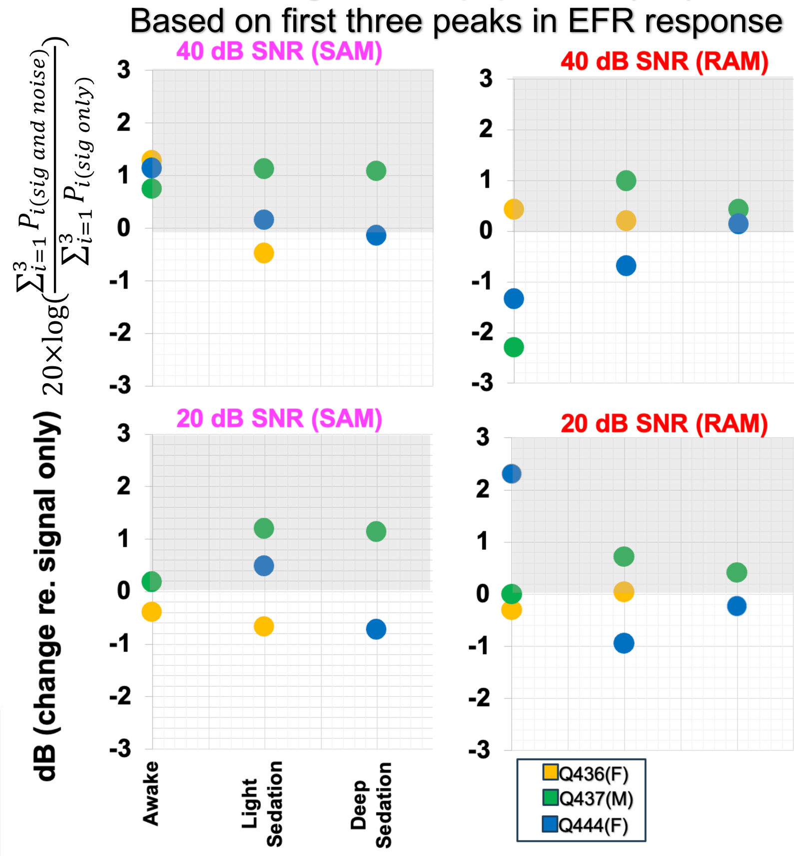
EFR responses



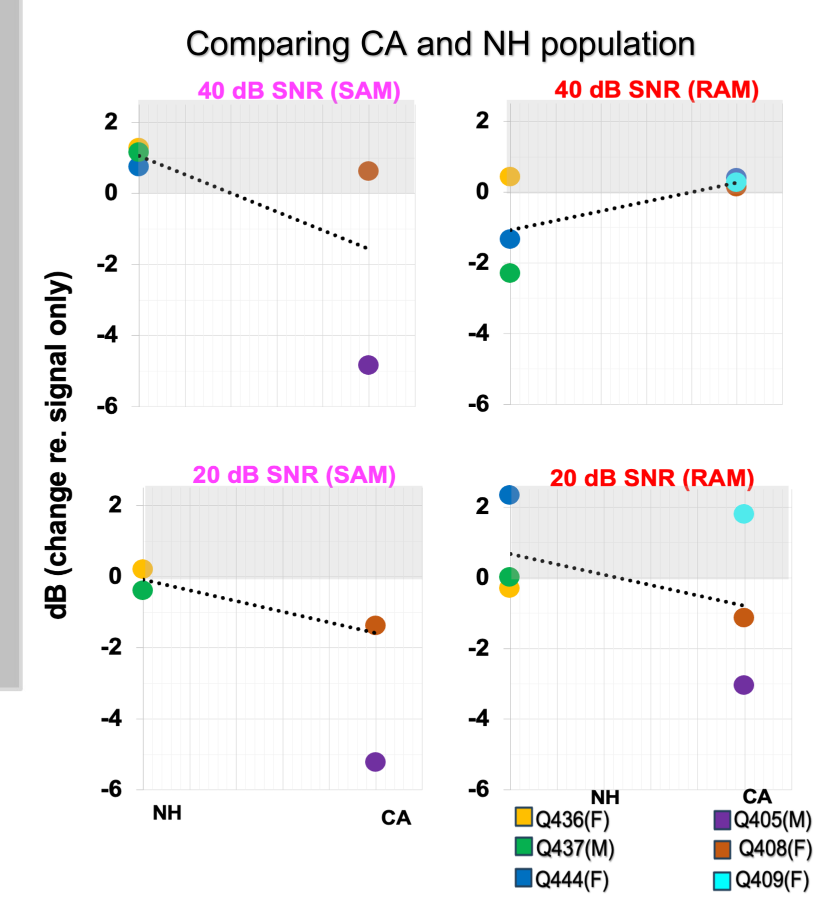

- Carboplatin exposure population has no modulation enhancement in almost all cases compared to normal hearing population.
- There is also more variability across CA population.

- Decreasing enhancement trend from awake to deep sedation observed in some cases
- Chinchilla (437, green) shows no apparent impact from anesthesia
- Enhancement effect seen at 40 dB SNR, but excessive noise suppresses it
- In RAM, more enhancement observed at 20 dB SNR compared to 40 dB SNR

Average across population (NH)
Based on first three peaks in EFR response

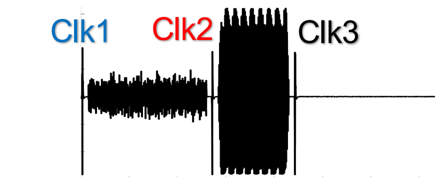


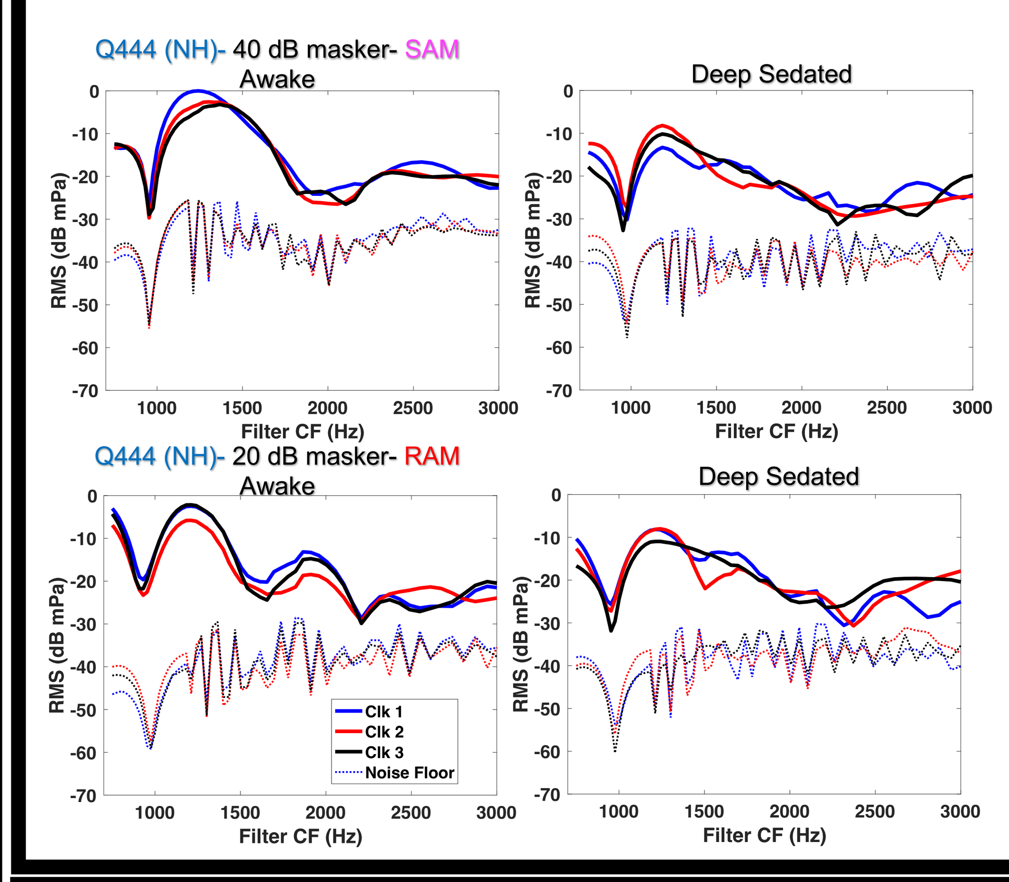

Comparing CA and NH population

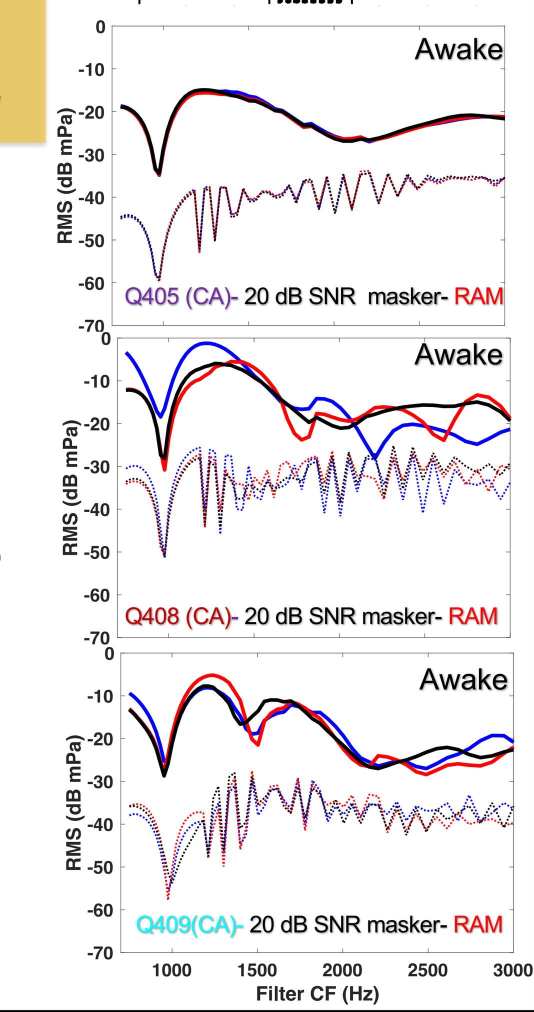



## TEOAEs

- TEOAEs <u>decrease</u> during the <u>noise</u> (Awake condition)
- Individual differences in EFR responses for CA chinchillas could potentially be correlated with differences in their TEOAEs
- Sedation changes the TEOAEs trends compared to awake condition.

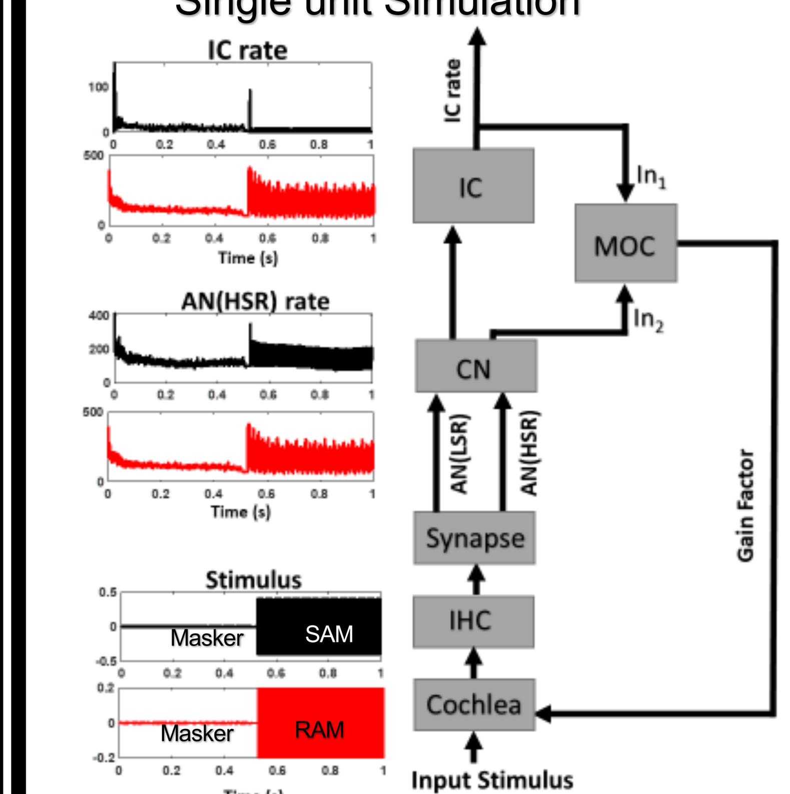


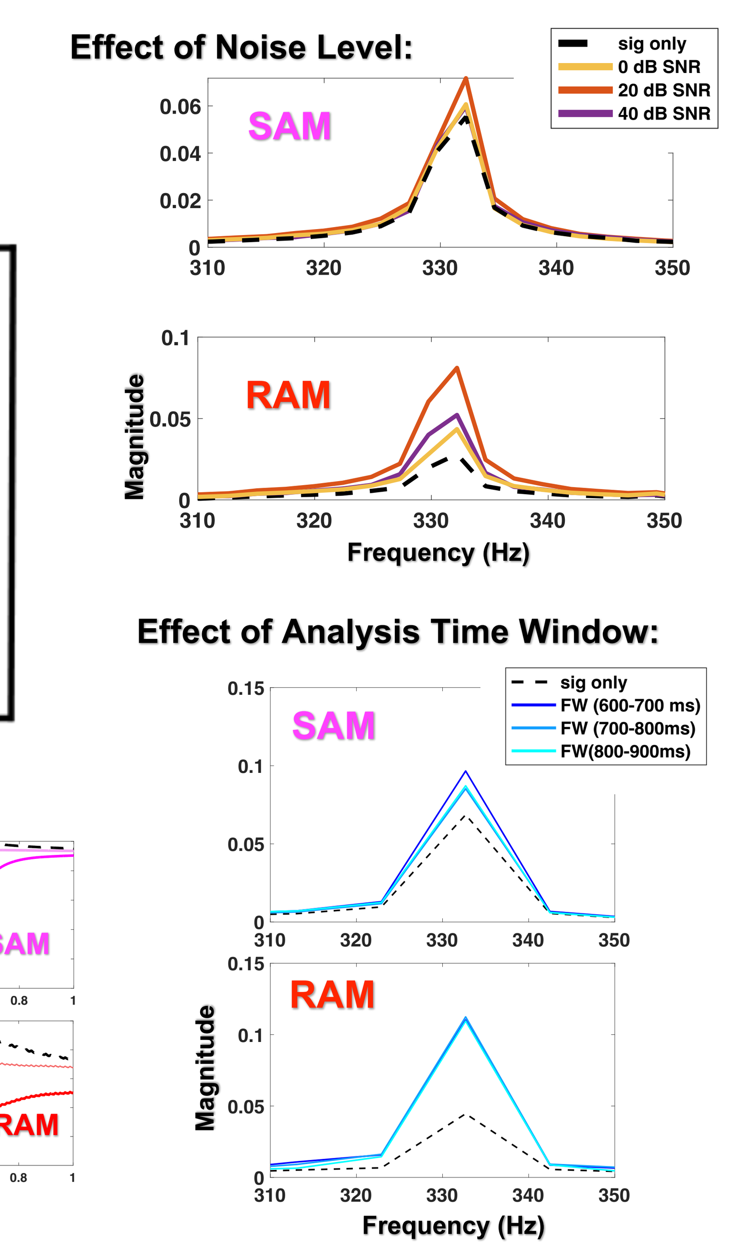




## Modeling Results

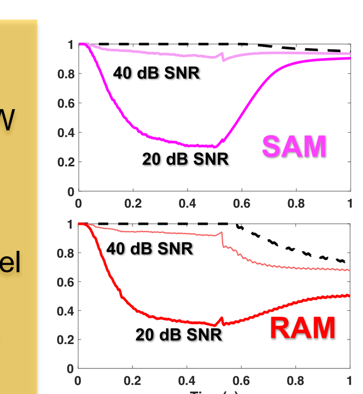
Single unit Simulation




**Evoked potential:**
**Based on Sum of AN and IC response Across CFs**




- Gain decreases during the <u>noise</u> and RAM (with no masker and with low noise FW masker).
- Gain increases in SAM
- The enhancement effect is level dependent based on the model responses
- Analysis time seems to be an important factor in enhancement effect.




## Conclusions and Future Work

- Enhancement in EFR response was observed for all NH chinchillas in awake condition but was reduced gradually from awake to low and deep sedated conditions.
- Chinchillas with Carboplatin exposure show virtually no enhancement in EFR response.
- TEOAE interleaved with EFR measurements seems to show some correlation between changes in emission and modulation enhancement.
- Computational modeling using a subcortical model with MOC efferent agrees with physiology observations.

-------------- Future and ongoing work --------------

- Collecting data from more animals will help us to learn about the neural mechanism behind these observations.
- Computational model can guide us with designing the experiment and choosing parameters such as sound level, modulation and carrier frequency, and different masker types (Gaussian, high/low frequency, Low noise noise), ipsilateral and contralateral noise.
- Analyzing time windows in the responses to see any gradual effect that could be related to the time constant of MOC.

## Reference


Supported by NIDCD grant R01DC009838 (M.H.)



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